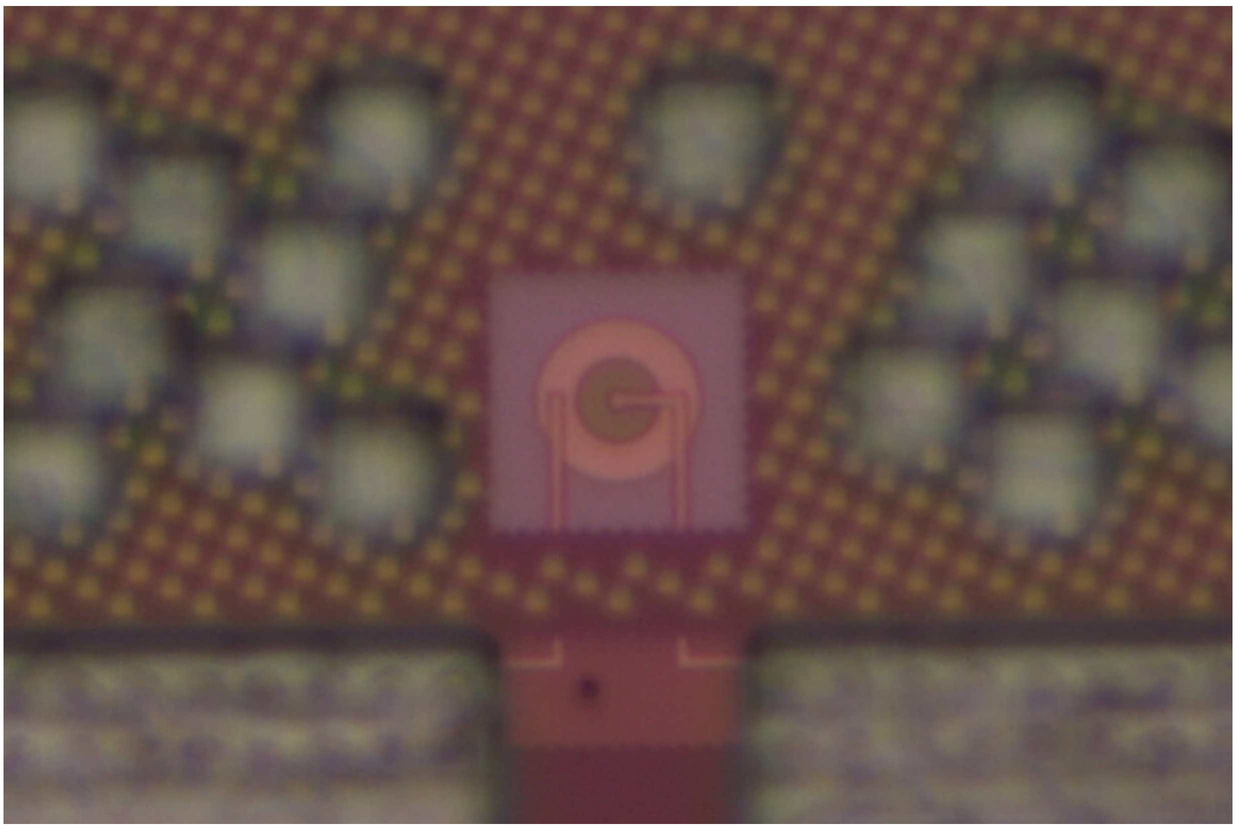
An LED that can be integrated directly into computer chips

December 14 2020, by Daniel Ackerman



MIT researchers have developed a bright, efficient silicon LED, pictured, that can be integrated directly onto computer chips. The advance could reduce cost and improve performance of microelectronics that use LEDs for sensing or communication. Credit: Courtesy of the researchers

Light-emitting diodes—LEDs—can do way more than illuminate your living room. These light sources are useful microelectronics too.

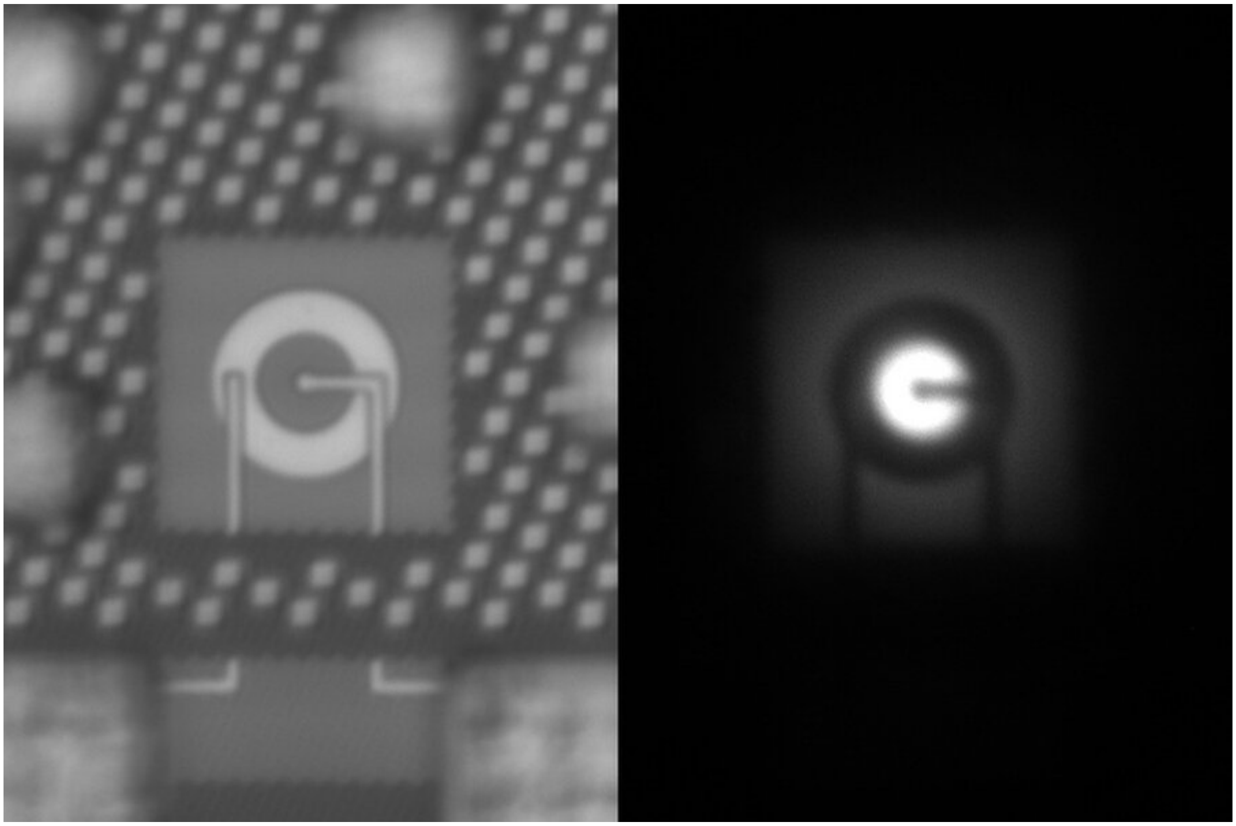
Smartphones, for example, can use an LED proximity sensor to determine if you're holding the phone next to your face (in which case the screen turns off). The LED sends a pulse of light toward your face, and a timer in the phone measures how long it takes that light to reflect back to the phone, a proxy for how close the phone is to your face. LEDs are also handy for distance measurement in autofocus cameras and gesture recognition.

One problem with LEDs: It's tough to make them from silicon. That means LED sensors must be manufactured separately from their device's silicon-based processing chip, often at a hefty price. But that could one day change, thanks to new research from MIT's Research Laboratory of Electronics (RLE).

Researchers have fabricated a silicon chip with fully integrated LEDs, bright enough to enable state-of-the-art sensor and communication technologies. The advance could lead to not only streamlined manufacturing, but also better performance for nanoscale electronics.

Jin Xue, a Ph.D. student in RLE, led the research. MIT co-authors included Professor Rajeev Ram, who leads the Physical Optics and Electronics Group in RLE, as well as Jaehwan Kim, Alexandra Mestre, Dodd Gray, Danielus Kramnik, and Amir Atabaki. Other co-authors included Kian Ming Tan, Daniel Chong, Sandipta Roy, H. Nong, Khee Yong Lim, and Elgin Quek, from the company GLOBALFOUNDRIES.

Silicon is widely used in computer chips because it's abundant, cheap, and a semiconductor, meaning it can alternately block and allow the flow of electrons. This capacity to switch between "off" and "on" underlies a computer's ability to perform calculations. But despite silicon's excellent electronic properties, it doesn't quite shine when it comes to optical properties—silicon makes for a poor light source. So electrical engineers often turn away from the material when they need to connect LED technologies to a device's computer chip.



These two images show the silicon LED switched on (left) and off. Credit: Courtesy of the researchers

The LED in your smartphone's proximity sensor, for example, is made from III-V semiconductors, so called because they contain elements from the third and fifth columns of the periodic table. (Silicon is in the fourth column.) These semiconductors are more optically efficient than silicon—they produce more light from a given amount of energy. (You don't see the light produced from the proximity sensor because it is infrared, not visible.)

And while the proximity sensor is a fraction of the size of the phone's silicon processor, it adds significantly to the phone's overall cost. "There's an entirely different fabrication process that's needed, and it's a separate factory that manufactures that one part," says Ram. "So the goal would be: Can you put all this together in one system?" Ram's team did just that.

Xue designed a silicon-based LED with specially engineered junctions—the contacts between different zones of the diode—to enhance brightness. This boosted efficiency: The LED operates at low voltage, but it still produces enough light to transmit a signal through 5 meters of fiber optic cable. Plus, GLOBALFOUNDRIES manufactured the LEDs right alongside other silicon microelectronic components, including transistors and photon detectors. While Xue's LED didn't quite outshine a traditional III-V semiconductor LED, it easily beat out prior attempts at silicon-based LEDs.

"Our optimization process of how to make a better silicon LED had quite an improvement over past reports," says Xue. He adds that the silicon LED could also switch on and off faster than expected. The team used the LED to send signals at frequencies up to 250 megahertz, indicating that the technology could potentially be used not only for sensing applications, but also for efficient data transmission. Xue's team plans to continue developing the technology. But, he says, "it's already great progress."

Ram envisions a day when LED technology can be built right onto a device's silicon processor—no separate factory needed. "This is designed in a standard microelectronics process," he says. "It's a really integrated solution."

In addition to cheaper manufacturing, the advance could also improve LED performance and efficiency as electronics shrink to ever smaller scales. That's because, at a microscopic scale, III-V semiconductors have nonideal surfaces, riddled with "dangling bonds" that allow energy to be lost as heat rather than as light, according to Ram. In contrast, silicon forms a cleaner crystal surface. "We can take advantage of those very clean surfaces," says Ram. "It's useful enough to be competitive for these microscale applications."

Ram is confident that his team can continue finetuning the technology, so that one day LEDs will be cheaply and efficiently integrated into silicon chips as the industry standard. "We don't think we're anywhere close to the end of the line here," says Ram. "We have ideas and results pointing to significant improvements."

Provided by Massachusetts Institute of Technology

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